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Design and Development of Chemical Free Sustainable Paper from Water Mosses

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Abstract

Water mosses are abundant in backwaters and other water bodies that often cause difficulties in water transportation and also reduce the amount of oxygen in the water bodies which may affect the survival of aquatic life adversely. Sustainable development put forwards a goal to meet the needs of today, without compromising the needs of the future. The depletion of current levels of resources can adversely affect the future generations. According to triple bottom line (TBL), sustainability is achieved by considering the environment, economic and social factors together. A way of achieving sustainable development is by using materials like water mosses which are abundant and hinder the aquatic life and water transportation. Reduction of CO_2 emission plays a vital role on preventing environment degradation. The amount of deforestation for the purpose of paper manufacturing has more impact on the increase of atmospheric carbon dioxide level than the combustion of fossil fuels. Hence, use of water mosses for the manufacturing of paper products has a good potential in attaining the goal of sustainable development. The paper discusses about developing a model which helps in manufacturing sustainable paper products from water mosses. The method involves process like shredding, boiling, blending and moulding to obtain the desired form. The by-products are minimum and can be used as organic manure. This paper further discusses about the importance of using water mosses which as discussed above harms aquatic life and transport, towards the sustainable development of paper products.

Keywords: Sustainability, aquatic life, triple bottom line, water mosses, shredding, environment degradation, blending, moulding

1. Introduction

Many of the current challenges faced by the humans such as climate change or water scarcity can only be tackled from a global perspective by promoting sustainable development. When trees are being cut, CO_2 escapes into the atmosphere. A deforested area cannot absorb and store more CO_2. Further, animals and indigenous people who once depended on forests for life are in danger for their existence. The Union of Concerned Scientists points out that wood products, including paper, proves to be the main reason for about 10% of total deforestation. Cattle, soybeans, and palm oil are the other major culprits. One of the seventeen main objectives set by UN for sustainable development includes, Care for the environment combating climate change and protecting the oceans and land ecosystems.

Water mosses such as water hyacinth are aggressive plants, which has been a terrible nuisance on almost all continents for more than 100 years. The problem has now grown to such levels that governments are at their near end. The biomass doubles its surface area in 14 days, and sometimes even in 6 days. Water hyacinths hover on the surface and set roots in the shallows. They grow and

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spreads by runners in which new plant bodies develop. There isn't one method of control that solace in the long term, except perhaps an integrated approach. Within this a modest role has been set aside for the production of paper products from biomass of these plants (Goswami et al., 1997).

There are two main things that are unavoidable to make paper: water and fibre. Chemically the plant fibres consist of cellulose, which is one of the main constituents of the cell walls. Fibres are present in different regions of the plant such as the stem, the leaf and the fruit. In order to make the plant fibres suitable for the manufacture of paper, the fibre has to be rendered soluble: which is the recovery or extraction process. This results in removing as much of the non-cellulose material as possible from the plant fibres.

These days every production process must be sustainable which includes paper and wood production. This makes non wood fibres an interesting option for the industry, especially for the paper industry in developing countries. The need for raw materials has clearly changed because of this. Originally the materials had to have a high and above all recoverable fibre content, today it is the durability factors that play the leading role. Other social forces, such as the international conservation movement and non-governmental organizations (NGOs) control and revive the trend towards sustainable paper production. Seen in this context the modest role that the water hyacinth now plays as a raw material for paper could in the future increase appreciably. The main objective of this research paper is to bring out a new method of manufacturing paper products without disturbing the nature and with the use of sustainable practices such as the use of water mosses as the raw material there by not only utilising the unwanted substances but also reduce the amount of deforestation.

2. Literature review

The paper categorizes literature review broadly into three sections. The first section examines need for sustainability in the current scenario. Through the second section, the integration of sustainability to the paper productions and recycling is studied. Third section deals with the various existing processes and methodologies in paper industries are examined.

2.1 Sustainability.

Sustainability is defined as "meeting our own needs without compromising the ability of future generations to meet their own needs". In addition to natural resources, social and economic resources are also a factor of sustainability. Sustainability is not just environmentalism. Embedded in most definitions of sustainability we come across concerns for social equity and economic development. It also represents that human civilisation takes resources to sustain our modern way of life. There are countless examples throughout human history where a civilisation has damaged its own environment and seriously affected its own survival chances, (Jared, 2005). Sustainability also considers how we might live in harmony with the natural world around us, protecting it from damage and destruction. Deepak et al. (2018) have pointed out that due to the importance given by the governments and other organizations to social, environment and corporate responsibility, sustainable development is now receiving more attention.

Environmental Sustainability

Ecological integrity is maintained, all of earth's environmental systems are kept in balance while the available natural resources are consumed by humans at a rate where they are able to replenish themselves. The environment sustainability referred to the specific practices assisted by technology that can reduce the environment impact. The environment practices may include preventing pollution, extracting materials capturing harmful pollutants followed by proper disposal (Vachon and Klassen, 2006).

Economic Sustainability

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Human communities across the globe are able to maintain their independence and have access to the required resources, financial and other, to tend to their needs. Economic systems are in order and activities are available to everyone, such as secure sources of livelihood. Practitioners and organizations are now looking on profits and profitability as only one element in the long-term success of companies and economies. Kleindorfer et al. (2005) have pointed out that there are many activities that adversely affect the footprint such as manufacturing and logistics, waste reduction and design innovation etc. The authors have also pointed out that the basic drivers of this sustainable economic movement are corporate image, regulatory compliance, liability and community relation which constitute towards regulations and employee health and safety, consumer relations etc. Porter (1991) argued that the conflict between environment protection and economic competitiveness is based on a narrow perspective and competition which can be addressed using technology advancement in the direction of sustainable development.

Social Sustainability

Universal human rights and basic necessities are attainable by everyone, with access to enough resources in order to keep their families and communities healthy and secure. Healthy communities have unbiased leaders who ensure personal, labour and cultural rights are respected and all people are protected from discrimination. A work is said to be socially sustainable when it provides a good living environment, reduces social inequality and improves the quality of life (Enyedi, 2002). Sustainability practices especially related to environment and economic factors of a focal organization cannot be fully realized without addressing the social condition in that place. Hence social sustainability factor should be one of the important factors to be considered for technology advancement.

2.2 Need for sustainability in paper industries.

Over 20 years ago, it was expected that the paper free office (or close to it) would be a reality by 2011. Ironically, since then print volume has increased, due to printing of emails, web pages, etc. In addition to that, paper used for packaging, tissue products and newsprint demonstrates how prevalent paper usage is on a daily basis. Indeed, when a Lifecycle Analysis (LCA) is conducted, it reveals how high the carbon footprint and environmental impact really are due to the resource-intensive processes used for manufacturing paper products. LCA affirms that reducing paper use and paper packaging of products can have a significant impact on reducing the carbon footprint of an organization, along with decreasing costs, and there is, in fact, a recent trend to decrease paper consumption in corporations, primarily because of the high costs of purchasing paper and printing.

The amount of deforestation for the purpose of paper manufacturing has more impact on the increase of atmospheric carbon dioxide level than the combustion of fossil fuels. Following an LCA procedure, the first area to evaluate is deforestation – the result of sourcing the primary material used for papermaking: wood. It is essential that the paper industry address this issue because more than 40 percent of industrial wood harvest is used for paper manufacturing in the US Recycling is only one part of the solution because paper can be recycled only five to seven times before the pulp fibres are too weak to be reprocessed, therefore necessitating the continuation of virgin wood papermaking practices. Fortunately, deforestation can be limited to a great extend through sustainable forestry.

Given the environmental problems caused by papermaking and the predictions that the industry will keep growing in spite of them, from an environmental perspective is an issue but big problems require big solutions, as in how innovation can transform industries and societies. Paper is not going to become obsolete anytime in the foreseeable future; however, if individuals and businesses focus on developing new processes and driving innovation, both to reduce the need for paper and make papermaking more sustainable, the problem can be much better managed (Richard, 2011).

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2.3 Current processes in paper industries.

Pulp is a material, fibrous in nature, which is obtained through complex chemical and mechanical treatment of various plant materials. In the present scenario, wood contributes to approximately 90% of raw material for global pulp production, while the remaining 10% is obtained from annual plants. Pulp is one of the most copious raw materials worldwide which are used predominantly as a major component in the manufacture of paper and paperboard and with increasing importance also in the form of wide variety of cellulose product in the textile, food, and pharmaceutical industries. (Asma Ismaili Hamida *et al*, 2017)

Paper is made up of a web of pulp fibres , usually formed from an aqueous slurry on a wire mesh or screen. The fibres are held together by hydrogen bonding. The basic steps involved for either hand- or machine-made paper are the same.

The steps are: 1. Forming - spreading pulp on the screen or mesh. 2. Draining - allowing water to drain by means such as gravity or a pressure difference developed by a water column. 3. Pressing - further removal of water by squeezing the sheet. 4. Drying - air drying or drying of the sheet over a hot surface. (J. Biermann, 1996)

In the last few decades many new woody and ago-based biomass sources have been evaluated, and the suitable sources accepted which are being utilized by papermaking industry. Eucalypts have always been and will continue to receive attention as an important fast-growing, short-rotation, renewable biomass crop for high quality paper production. The growth cycle of eucalypts is very fast and it gives a high pulp yield with excellent properties which makes it suitable for manufacturing a wide range of papers. Research reveals that eucalypts pulp has better intrinsic pulp properties (tensile/density relationship, etc.) as compared to other raw materials used in the paper industry. Based on pulp property analysis, the eucalypts pulp showed a very good potential for applications in value-added paper and paperboards. (Vikas Rana *et al*, 2014)

The banana plant does not only provide with the banana fruit but also offers banana fibre. All varieties of banana are known to offer fibre abundantly. Banana fibre is characterized as best fibre and is renowned as a good source of fibre in countries such as Nepal, Japan, Philippines, Paraguay and India. Fibbers occur in almost any part of the plant: leaves, pseudo-stem, seeds, fruits and fruit peels. An acre of land can generate roughly 1000 to 1500 pseudo-stems and from this output, approximately 10 to 13 of these stems are required to produce 1-2 kg of banana fibre. The banana plant is an excellent source of cellulosic fibres which can be seen in the PPI for its suitability as pulp. The banana peel which is discarded as waste can also be utilized for pulp production. (Amit *et al*, 2017)

Sources like banana fibre and carpet grass have previously been commercialized as substitute. The use of pineapple leaf fibres as a raw material for paper production is considerably new in the industry. Pineapples cultivated under selective breeding were researched to have higher cellulose content than

wood fibre, and hence indicate that such non-timber fibre make good substitutes. Other than reduced felling of trees, other benefits regarding the plant itself includes short growth cycles and low lignin content thus improving use of energy and chemicals during pulping process. The pineapple leaves which would be sent to the landfill as a waste could instead be used for its true value as source of natural fibres. (Stephen *et al*, 2017)

3. Methodology

The process of conversion of water mosses to organic paper is carried out in different stages. The major stages follow these sequential operations: Shredding, boiling, blending, moulding and Pressing, drying. The process starts with shredding of the mosses into fine processable form. This is to make sure that the mosses do not get entangled in the moving/rotating parts of the shredder. In the shredder, the mosses first pass through a pair of rollers before going to the blades. The roller serves the function of providing a uniform feed rate to the blades as well as squeezing the mosses for easy cutting. The shredder blades cut the mosses into fine pieces and these pieces leave the shredder via a duct which opens up to the boiler. Boiling is done to loosen the fibres in the mosses for easy extraction. The incoming mosses from the shredder are filled in a boiler containing water. The boiler is cylindrical in shape. The mosses are then boiled for 90 minutes. After boiling the structure of the mosses gets broken down and some of the fibres are separate from the mosses. For separating the remaining fibres and making slurry, it is sent to a blender. The stages used for the development sustainable of paper products from water mosses are shown in Figure 1.

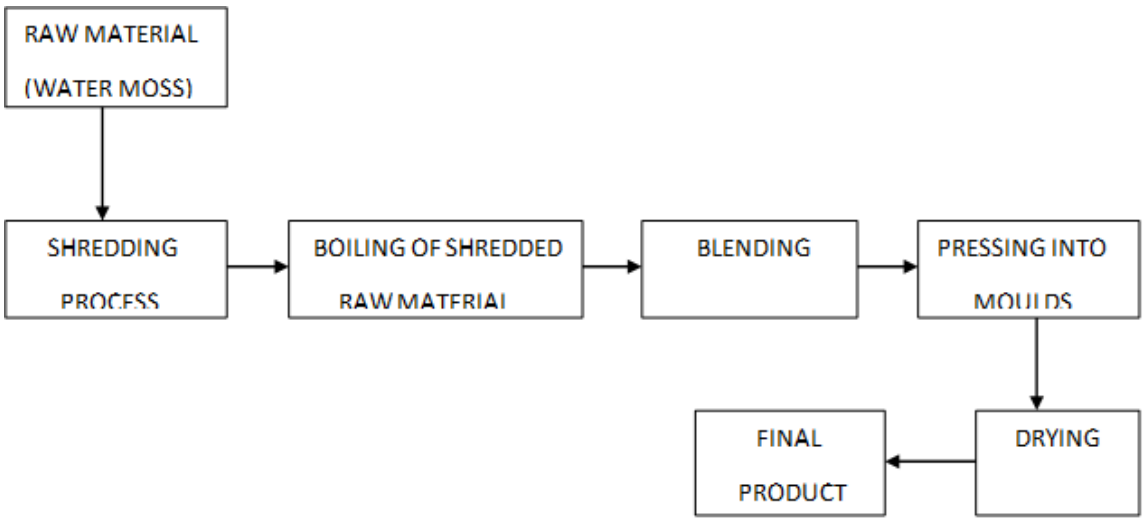

Figure 1 Schematic diagram of the process

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The blender serves 2 main functions: To separate all the fibres from the boiled mosses and to make slurry consisting of fibre and water. The blender is also cylindrical in shape and has 2 wheels mounted at the ends of a shaft which is perpendicularly mounted on a central vertical shaft and undergoes precession. This motion blends the fibres with water and forms a uniform fine slurry. The slurry is then sent to a tray and spread uniformly to ensure homogeneity of the paper. A mould containing fine sieve is then dipped in the slurry and taken out in such a way that a layer of plant fibres is collected over the mesh. The size of the sieve is very small so as to ensure that the fibres don't pass through it, hence only removing the water. After the removal of water, a fine layer of fibre is then formed on top of the mould. This is then pressed in a hydraulic press, if necessary and is then dried.

The drying can be done either by natural convection or by forced convection using a fan or a heater. Natural convection is a time-consuming process and hence we use forced connection. The final product produced after drying is organic paper. Also, the slurry that is left in the tray is rich in nutrients and can be used as organic manure, thus making the process 100% waste free.

4. Design of the proposed model

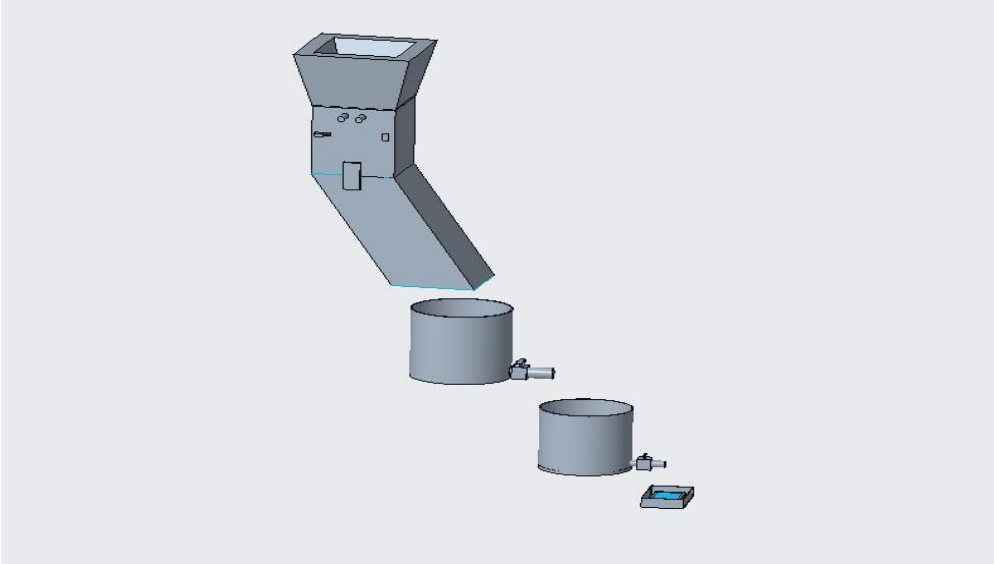

Figure 2 Exploded view of the proposed design of the model (Author own preparation)

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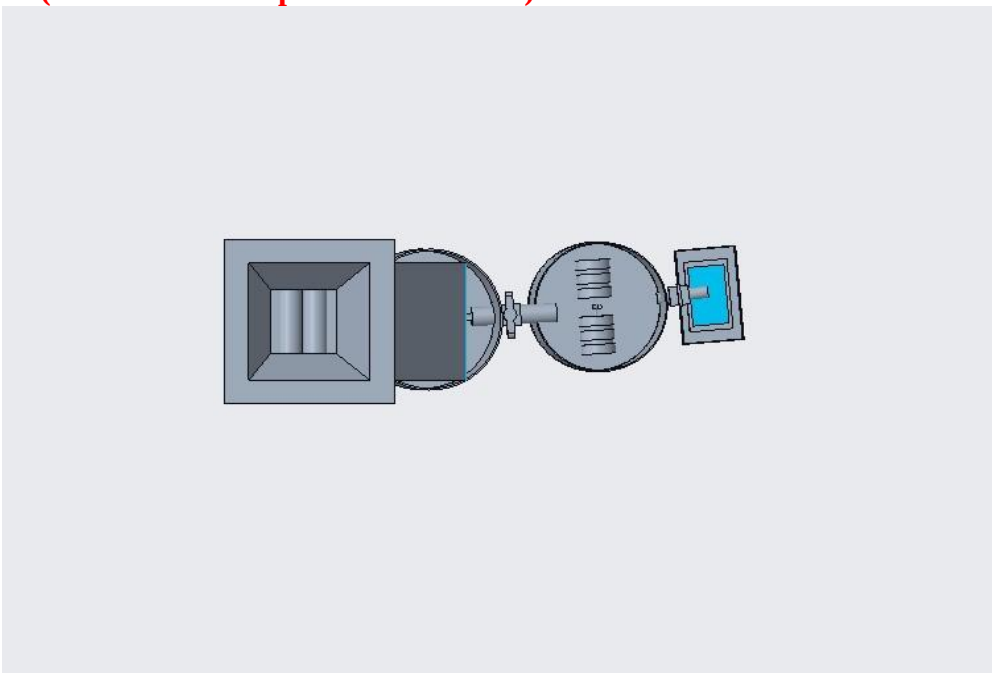

Figure3 Top view of the proposed design of the model (Author own preparation)

5. Limitations

The major limitation of this process is that the properties and quality of the final product depends on the type of plant fibres used, also the type of raw material depends on the vegetation and topography of the area. the quality and finish of the final product can be improved by using certain enhancing agents, but the addition of such agents can lead to the formation of waste. Another factor which adversely affects the efficiency of the process is that, complete removal of water mosses from their habitat may disrupt the balance of the ecosystem. The developed model in this paper need to be analysed, fabricated and verified for further development which can be a scope for future study.

6. Conclusion

The use of sustainable paper products eliminates the need for deforestation. Further, the waste produced in the paper production process can be minimized. The methods and processes involved in the production of sustainable paper products have been designed and developed in this paper.

This process emphasizes the use of unwanted aquatic plants or water mosses in paper production. Their stems consist mainly of parenchyma cells with minimal conducting tissue and large volumes of intercellular space. All of the other genera contained fibres, varying in length from 0.5 mm up to 3.25 mm (Potamogeton). Invasive flora and fauna are a major cause of biological stress. A major flora stressor is Water Hyacinth (Eichhornia crassipes),

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which is widespread in regions like Alleppey and other parts in the state of Kerala, India. They can form as thick mats over the entire water surface of slow flowing rivers, lakes, and wetland complexes, where nutrient levels are high. Invasive species often have major impacts as predators, herbivores, competitors, and ecosystem engineers. Additionally, when an invasive species is closely related to native species, hybridization with the native species can result in loss of native genetic diversity. The use of such invasive species in paper production helps in reducing the biological stress and also helps in reducing the raw material cost. This paper has focused mainly in the design and development of a technology which can lead to the sustainable development.

The paper industry faces a series of challenges to the generation of large amounts of wastes whose disposal entails significant costs. Substantial quantity of water is used in paper production processes in the pulp and paper industry, which varies according to the quality and kind of paper manufactured. In the end, substantial amount of solid waste, waste water, and gaseous emission have taken place. Control of such emissions can also be done by using water mosses as raw materials. Further, the by-products will be organic manure. Hence, designing and developing a model for addressing the waste generation in paper industry and use of water mosses as the raw material is one of the major contributions of the paper. The designed model needs to be further refined for future cause.

Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

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Author Biography

Ahmad Thwayyib is an undergraduate student doing his bachelor’s degree in Mechanical Engineering at Mar Athanasius College of Engineering, Kothamangalam and will be graduating in 2020. Thwayyib has a strong interest in the field of sustainable development and alternative energy sources.

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